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Influence of drying methods on the quality of sage *(Salvia officinalis),* parsley (*Petroselinum crispum)* and nasturtium (*Tropaeolum majus*).

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ABSTRACT

The aerial parts of sage *(Salvia officinalis),* parsley (*Petroselinum crispum)* and nasturtium (*Tropaeolum majus*) cultivated in Egypt were collected and dried by different drying methods. Air and oven-drying at 40 °C produced dried sage and parsley contain higher amounts of essential oils. Essential oil constituents of air and freeze dried parsley samples were almost similar in comparison with fresh ones. Oven drying at 90 C adversely influences on essential oil quality resulting in a significant increase in some components. Air drying, oven drying (40 C) and freeze drying do not have significant effect on the chemical constituents of sage oil. By contrast, chemical constituents of sage essential oil are strongly affected by solar drying and oven drying (90 C) where it caused greater changes in aroma. Drying methods had no significant effect on the content of flavones in parsley while freeze drying and oven- drying at 40 °C exhibited the highest maonylapiin / apiin ratios. In nasturtium, Freeze-dried samples contained the highest levels of glucotropaeolin. The glucotropaeolin concentrations decline to about 80% and 70% of the original amount by using air and oven drying at 40 °C respectively.

Keywords: sage, parsley, Nasturtium, Drying methods, Essential oil, Flavones, polyphenols, glucotropaeolin

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INTRODUCTION

The majority of leafy aromatic plants (known as herbs) are marketed dried since they contain high moisture content (78–82%, w/w). Moisture content in the final product should not exceed 15% and generally is around 5%. Also, for various medicinal plant species a maximum value of final moisture content is prescribed in different pharmacopoeias all over the world showing a range between 8 and 12% [1].

Parsley and sage like many other herbs contain highly water content in nature. In order to preserve these seasonal and highly perishable plants and make it available to consumers all year round at low prices, it is subjected to postharvest technological treatments such as drying.

Drying is of a great concern for medicinal and aromatic plants in the production chain. It represents a very important aspect for postharvest management allowing conservation of herb quality during storage since it reduces shipping capacities and minimizes packaging requirements. Moreover, drying process may also contribute to a regular supply and facilitate the marketing of plants, because drying results in reduction of the weight and volume of the herb to allow proper conditions for storage, and for the long-distance transport [2-3].

Also, drying reduce the water content in order to inhibit microorganisms growth and minimize the biochemical changes and enzymatic reactions, and thus extend the shelf-life of the bio-origin products and ease of transportation. Drying leads to a stable, simply moveable and permanent product for an elongated period in order to be available in markets year-round [4].

In addition, herb organoleptic characteristics should be maintained; mainly sensory quality such as flavor, aroma and color which are the main attributes influencing consumer acceptability. Since aroma is the main characteristic of herbs, drying is aimed to achieve the high quality standards required herbs and to retain the raw material's character [5-6].

It is well-known that the choice of both drying method and its conditions is critical for the end product since they may lead to unacceptable alterations in appearance, texture, off-odors, change of color or loss of volatiles profile. To minimize the magnitude of these alterations we must concerned with the implemented drying methods and its conditions.

The American Herb Society (http://www.herbsociety.org/herbs/) lists parsley and sage as of the ten most popular culinary herbs. Most recent, spices and seasonings have been introduced in a variety of public and international dishes. Parsley is classified as a spice that is widely applied in many recipes such as pasta, soup or salad in both dried and fresh form. Nasturtium is considered as an invasive species in many countries and it is recognized as a medicinal crop

Parsley (*Petroselinum crispum* L.) is biannual herb native to the countries of the Mediterranean region and grown widely in the temperate and subtropical areas throughout many parts of the world (Europe, USA and western Asia) [7].

As a medicinal plant, It is used as a carminative, diuretic, hypertensive, hypotensive, stomachic, nervine, emmenagogic, abortifacient and nutritive agent [8-9]. Antimicrobial and weak antioxidant activities of parsley essential oil have been reported by [10].

The characteristic aroma of parsley leaves was initially associated with the major components, namely, p-mentha-1,3,8-triene, β-phellandrene [11]. A subsequent study carried out by [12] reported that the aroma of curly leaf parsley was derived from a mixture of seven constituents, including myrcene, 1,3,8-p-menthatriene and myristicin. In the absence of myrcene and 1,3,8-p-menthatriene, there was a deterioration of the parsley aroma.

Nasturtium (*Tropaeolum majus*) is a herb indigenous to South America. Leaves, pickled fruits and flower buds can be used for seasoning. Besides, it is used in mixture with other products as herbal medicine against urinary tract infections in Germany. Consistently high glucotropaeolin (GTL) content in the plant allows direct preparation of a mono-drug without any prior extraction procedure, thus reducing the production costs and avoiding losses of intact glucosinolates during extraction. . Since the leaves were the primary site of

benzylglucosinolate synthesis [13] it contains high amounts of the glucosinolate glucotropaeolin [14]. When Tropaeolum leaves are eaten, glucotropaeolin is hydrolyzed to yield mustard oils, which are absorbed in the intestine and excreted in the urine, showing antimicrobial activity.

Traditionally, the leaves are reported to possess wide pharmacological properties such as antibacterial, antifungal, antiseptic, aperient, depurative, expectorant, purgative, vulnerary, antineoplastic, demulcent, laxative and stimulant activities. Additionally, extracts and preparations have natriuretic and diuretic [15], hepatoprotective [16], anti-inflammatory activities [17].

Sage (Salvia officinalis L.) belonging to labiatae family, is used as a culinary herb and spice and utilized in food formulations as food flavoring [18], preservative against food spoilage [19]. Furthermore, it is employed even as a fragrance in cosmetics and perfumes production.

Sage is used for remedial purposes as carminative, diuretic, antiheroic, analgesic, expectorant, disinfectant. Sage leaves and its essential oil have been documented as possessing antioxidant and anti-inflammatory activities [20-21] associated with the presence of high total phenolic content such as carnosic acid, carnosol and rosmarinic acid [22].

The chemical composition of sage oil from various geographical origins was examined in several studies. The main constituents of different sage oils include α- thujone, β-thujone, camphor, and 1,8-cineole [23-24].

Several studies investigated the influence of drying methods and emphasized that characteristics of herbs and the concentrations of the volatile compounds depend on several factors, such as the drying method and the herb concerned. For example, oven drying at 45 °C and freeze-drying caused a decrease in the concentrations of the majority of the volatile components, especially those with the greatest impact on parsley aroma: *p*-mentha-1,3,8-triene and apiole [25].

Also, results showed that air drying sage contained more total phenolics, antioxidant activity, and flavonoids than oven drying while; fresh sage had the lowest content of total phenolics [26].

The effect of drying in an oven at 30 °C and of freeze-drying on the total content of volatile compounds in sage was negligible. However, losses were higher when drying was carried out at 60 °C. It is well known that the higher the drying temperature, the greater the killing force on microorganisms. But a thermic overload could dangerously decline the quality of essential oil; Venskutoins (1997) observed lower losses in volatiles of sage at 30◦C and higher losses (31%) when submitted to oven drying at 60 c with respect to the fresh herb [27].

On the other hand, air drying produced better results than freeze drying in parsley whereas, retain better color at 60 _C compared to 50 _C [28] but [29] found that drying in temperature of 60 _C was found to be the optimum temperature for parsley leaves.

Heat pump and cabinet drying methods reduced the amount of volatile components of parsley with increasing temperature. However, there was no significant difference in the organoleptic tests [30].

In this study, nasturtium served as a model plant to develop process methods that prevent the hydrolysis substances. Further test plants in addition sage and parsley have been used to take into account other relevant plant secondary classes, which can cause problems during drying due to their high volatility or their sensitivity to oxidation. Therefore, the objectives of this study were to evaluate the effects of five different drying methods on sage, parsley and nasturtium, to compare the volatile profiles obtained from different drying types and to determine the best drying method allowing the production of the maximum levels of bioactive compounds.

MATERIALS AND METHODS

To implement the optimal drying conditions and to investigate the influence of different drying methods on the concentrations of secondary compounds of parsley (essential oils, flavones, polyphenols), sage (terpenes) and nasturtium (glucosinolates), the fresh materials of the three experimental plants (*Tropaeolum majus*, *Salvia officinalis* and *Petroselinum crispum*) were dried by the following methods:

- Air drying in room temperature
- Oven drying at 40°C
- Oven drying at 90°C
- Solar tunnel drying
- Continuous belt drying as used by the Fridal company
- Freeze drying

In each case, 100 g fresh herb from every plant was dried by using the different methods and the samples were replicated 10 times. After drying, dry weights and the essential oil contents were determined in each replicate for parsley and sage.

In the case of freeze drying of Nasturtium the samples were shock frozen in liquid nitrogen and kept in the freezer at -30°C until the drying procedure.

Representing samples of dried herbs of each replicate were subjected to hydro-distillation for 3 hours using Clevenger apparatus to extract and to determine essential oil percent according to [31]. The resulted essential oil was separately dehydrated over anhydrous sodium sulphate and kept in silica vials with Teflon-sealed caps and stored at 2^{o}C in the absence of light till GLC analysis. The percentage of extracted essential oil was determined and recorded on the basis of oil volume to herb dry weight (ml/100g dry herb).

The dehydrated oil of each treatment was subsequently analyzed using a gas liquid chromatography-mass spectrometer (GC-Ms) to evaluate oil quality. The analysis of total polyphenolic content was carried out with the Folin-Ciocalteu's method by [32]. The total phenolic content was expressed as gallic acid equivalent through the calibration curve of gallic acid.

HPLC analysis of glucotropaeolin was performed using a RP 18 column (250 x 4 mm) according to the method of [33]. Based on the peak areas of glucotropaeolin and the internal standard, the amounts of glucotropaeolin were calculated. Total flavone concentration was determined according to the method of [34]. and calculated by summing the amounts of the three major flavones: malonylapiin, diosmetin apiosyl gluco-side and diosmetin malonyl apiosyl glucoside. The identification of the individual components was carried out by mass spectrometry.

The collected data were subjected to the analysis of variance in Randomized Complete Block Design (RCBD) arrangement according to [35] using MSTAT-C V.2.1 software package [36]. Differences among means were compared for each trait by Duncan multiple range test (DNMRT) [37].

RESULTS AND DISSCUTION

Effect of the drying methods on moisture content:

Before drying process, initial moisture contents of the fresh parsley, sage and nasturtium were determined (83%, 88.32% and 81.5, respectively). After drying, air dried samples had the highest moisture content as compared to other samples of parsley, sage and nasturtium (Fig.1).
Oven-dried (90 °C) and fridal dried samples contained significantly less moisture content than the other samples in sage and parsley. Solar dried sage and freeze dried parsley contained relatively high moisture contents in compared to other dried samples. As unexpected for nasturtium, the moisture content was lowest in freeze dried samples, followed by solar drying while significantly higher values were recorded in oven dried (90 °C) and fridal samples.

Moisture content in the dried parsley, sage and nasturtium was found to be in the range recorded by [38] who reported that final moisture content at 8% is ideal because moisture content lower than 8% could accelerate pigment destruction or below 4% causes an excessive color loss and above 11% allows mould to grow.

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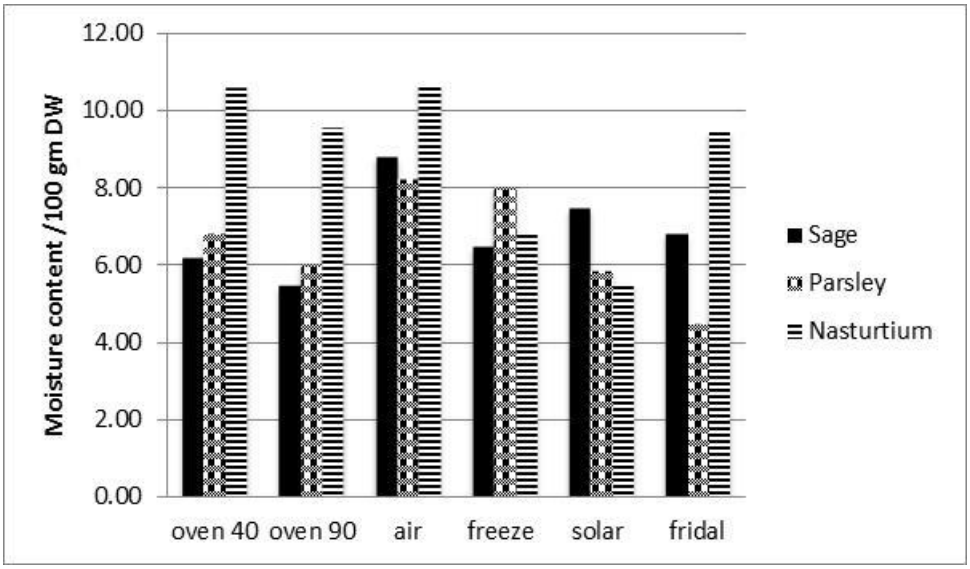

Fig (1): Effect of the drying methods on moisture content of Sage, Parsley and nasturtium after drying at 105 C^{O} in the oven.

Effect of the drying methods on dry matter content (%) and essential oil contents:

Results showed that drying methods had a significant effect on dry weight % of parsley, nasturtium and sage (Table 1). Freeze dried samples retained the highest dry weight followed by solar tunnel dried samples which were nearly the same in most cases. Also, oven (40 °C) and air assisted drying produced dried sage, parsley and nasturtium with relatively higher dry weights. All the dry weights of oven-dried (90 °C) and fridal samples were lower compared to other drying methods with no notable differences between them.

Table (1): Effect of the drying methods on dry matter content (%) of sage, parsley and nasturtium and on the essential oil contents of sage and parsley

Drying Methods	Sage		Parsley		nasturtium
	Dry weight %	Oil (%)	Dry weight %	Oil (%)	Dry weight (%)
Air dried	24.16 a	1.02 a	16.11 b	0.43 a	17.64 b
Oven 40 °C	24.55 a	0.89 b	16.25 b	0.40 b	17.72 b
Oven 90 °C	21.04 b	0.20 e	14.09 c	0.12 e	16.61 c
Solar tunnel	24.21 a	0.42 d	18.26 a	0.35 c	18.26 ab
Fridal method	19.27 b	0.34 d	13.36 c	0.07 f	15.50 d
Freeze dryer	24.98 a	0.77 c	17.65 a	0.27 d	18.73 a

In general, oil content of dried sage and parsley was strongly affected by drying methods. Although air drying (at room temperature) is one of the most time-consuming drying methods it produced dried sage and parsley materials contain higher amounts of essential oils when compared to other drying methods. Also, oven drying (40 ◦C) exhibited high levels of essential oils in sage and parsley.

In contrast to sage, freeze-drying was not suitable for the drying of parsley in terms of the essential oils, since the loss amounted to about 37 % compared to the air drying. In the same manner and in contrast to parsley, solar drying was not suitable for drying sage which caused marked loss of volatile by 59 % compared to the air drying.

As expected, oven drying (90 ° C) and fridal method (also at 90◦C) resulted in the highest losses. Oven-drying at 90◦C and fridal drying method induced losses in oil content by 80 and 66 %, respectively in sage and by 72 and 83 % respectively in parsley with respect to air drying.

So, in regard to the avoidance of losses of essential oils during the drying; solar tunnel dryer for parsley and oven (40 ° C) or freeze dryer for sage are the best alternatives.

Numerous research works investigating the impact of different drying methods on the essential oil content and chemical constituents of the essential oil plants. Results agreed with our data and revealed that drying methods had a significant influence on oil content and composition of aromatic plants. Air drying at ambient temperature resulted in few losses in volatile compounds of parsley compared with the fresh herb

[25]. Oven- and freeze-drying of parsley resulted in significant losses of volatiles compared to fresh herbs whereas they exhibit a lower effect in sage [5].

Effect of the drying methods on chemical composition of essential oil of parsley:

As shown in Table 2 the principal components of curley parsley oil were identified as Myristicine (ranged from 31.76 % to 50.64 %) followed by β- Phellandrene (ranged from 20.35 % to 12.52 %), Menthatriene (ranged from 12.69 % to 16.59 %). Myrcene, terpinolene, p-Cymene, β- Elemene, limonene and sesquiphellandrene were present in smaller amounts.

Table (2): Effect of the drying methods on chemical composition of essential oil of parsley

Compound	Fresh	Air drying	oven drying 40°C	oven drying 90°C	Solar drying	Freeze drying
Myrcene	4.85	3.15	2.54	12.03	3.29	5.84
Limonene	2.04	2.69	2.14	12.73	1.39	2.33
β-Phellandrene	17.51	15.00	12.68	11.70	13.33	18.50
Terpinolene	4.33	1.85	1.38	1.95	3.88	4.25
Cymene	3.09	6.72	4.96	1.79	3.03	2.19
1,3 Menthatriene	14.10	13.7	10.42	2.65	12.55	11.46
β -Elemene	2.64	2.04	4.10	7.02	4.53	3.40
Sesquiphellandrene	2.02	t	0.56	3.11	2.52	1.96
Myristicine	43.93	44.65	53.62	40.27	50.98	43.52

Essential oil constituents of air and freeze dried samples were almost similar in comparison with fresh ones. Oven drying at 90 C adversely influences on essential oil quality resulting in a significant increase in some components (myrcene, limonene and elemene) which were found to be unimportant compounds in fresh samples. Also, the amount of menthatriene was lessened when compared to other drying methods, and this may be lead to dried parsley with an undesirable aroma.

Also, Fewer changes in aroma were also assessed of both oven dried at 40 C and solar tunnel dried samples since it caused an increase in the concentration level of myresticine and slight decreases in β -phellandrene and 1,3,8 menthatreine.

Previous studies have been performed on the effect of drying on the aroma of parsley. For example, [25] reported that air-drying preserved more parsley (*Petroselinum crispum* L.) volatiles compared with oven-drying at 45 °C and freeze-drying. The volatiles lost using the latter methods are those monoterpenes with the greatest effect on parsley aroma, *p*-mentha-1,3,8-triene and apiole. Another study confirmed that air-drying preserved more of the herbaceous aroma characteristics of fresh parsley than freeze- and oven-drying [5]. Also, [30] reported significant losses of compounds (including 1,3,8-*p*-menthatriene, pinene, myrcene and phellandrene) during the drying of parsley leaves when used a higher temperature (45–65°C) than in samples were force-dried in cabinets or with the aid of pump driers.

Although drying was apparently beneficial for the composition of the essential oil of turnip-rooted parsley leaves (1,3,8-*p*menthatriene increased), it was less beneficial for plain-leafed parsley (the increase in *β*-phellandrene was accompanied by a loss of 1,3,8-*p*-menthatriene) [39].

These differences in volatiles can be attributed to the structure of the plant, the interaction between volatiles and water vapor and the hydrophobic nature of volatiles [40]. A loss of the characteristic parsley aroma intensity was found during drying at 70 ^{o}C and the formation of a new flavor known as ‘‘hay-like’’ [12].

Effect of the drying methods on chemical composition of essential oil of sage

Drying process has a different effect on the dried product depending on the drying method and its condition. Air drying, oven drying (40 C) and freeze drying do not have significant effect on the chemical constituents of sage oil since the dried sage that obtained by these methods were similar in comparison with fresh sage (Table 3). Air and oven drying (40 ^{o}C) is the most suitable for obtaining a higher percentages of α -thujone and β -thujone whereas sun-drying method is preferable for obtaining special components such as 1,8-cineole.

By contrast, chemical constituents of sage essential oil are strongly affected by solar drying and oven drying (90 C) where it caused greater changes in aroma showing decreases in the concentration level of the main compound alpha-thujone. Also, oven dried sage at 90 C presented higher amount of viridiflorol and manool compared with other drying methods.

Table (3): Effect of the drying methods on chemical composition of essential oil of sage

Compound	Fresh	Air drying	Oven drying 40°C	Oven drying 90°C	Solar drying	Freeze drying
α-Pinene	2.68	1.95	2.275	1.06	2.13	2.265
Camphene	3.445	2.635	3.245	2.41	2.495	3.03
β-Pinene	2.75	2.125	1.88	1.35	t	1.93
1,8-Cineol	8.88	7.875	8.655	5.25	13.45	7.8
α -Thujone	35.155	34.815	34.135	23.53	12.855	30.405
β -Thujone	9.995	9.795	12.585	7.2	12.41	10.75
Camphor	21.885	21.935	19.945	17.11	34.745	22.165
β -Caryophyllene	1.47	1.835	1.985	1.92	2.275	1.15
α -Humulene	3.545	4.21	2.38	5.25	5.095	4.505
Viridiflorol	4.355	4.73	5.395	11.41	9.74	8.22
Manool	1.22	2.715	3.985	11.22	2.505	4.875

During this process, evaporating water may drag many compounds to the leaf surface which had been lost [41].

In addition, camphor amount of solar dried sage was greater than those of other drying methods. The thermic excess could dangerously damage the quality of essential oil. The main components of sage essential oil were 1,8-cineole, α and β-thujone, camphor, viridiflorol, and manool concentrations increased significantly, particularly when drying sage at ambient air [42]. On the other hand, another study concluded by [43] smaller changes have been observed when freeze-drying was used as the drying method, and have been reported to retain an appearance and aroma that more closely resemble those of the fresh products.

From our results mentioned before it is evident that there is no standard method for drying herbs; all methods have benefits and drawbacks, and the choice (besides the economic regards) mainly depends on the desired result (appearance, scent or active constituents) of the final product and the requirements of its market destination. Also, conditions of drying can affect the essential oil content and components of the herb, which are a critical factor in its quality.

Effect of the drying methods on flavone contents and maonylapiin/apiin ratios of parsley:

Results presented show very clearly that the individual drying methods due to the different secondary metabolites have a very different impact on the product quality.

In contrast to the above-described concentrations of essential oils, drying types had no significant effect on the content of flavones in parsley. However, the Maonylapiin / apiin ratios differ in the different types of drying. Freeze drying and oven- drying at 40 °C exhibited the highest maonylapiin / apiin ratios. (Fig 2).

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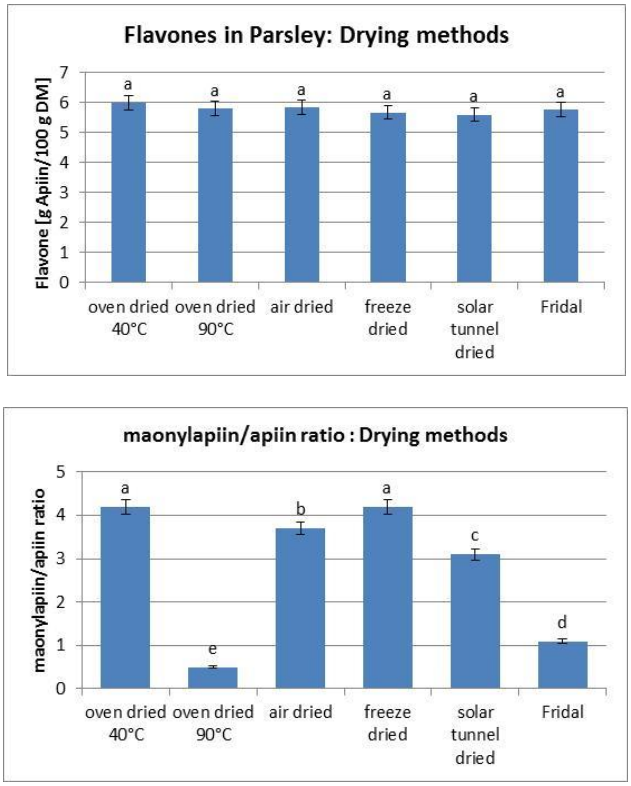

Fig 2: Effect of the drying methods on flavone contents and maonylapiin/apiin ratios of parsley.

Effect of the drying methods on polyphenol contents of parsley

Oven dried Parsley has been shown to contain high amounts of polyphenols even if it was at 40 or 90 ° C followed by freeze dried samples when compared to various drying methods (Fig. 3). Air drying and solar tunnel drying contained the lowest amounts of polyphenols. The loss of phenolic compounds in the case of air drying is probably attributed to the prolonged air drying where the air-dried samples had been dried for 10 days, while the oven-dried for 3 days indicating that as the length of drying time increased, phenolic compounds decreased. On the other hand, These results are inconsistent with the results of [28] who found that spearmint dried by convection oven presented the lowest amount of phenolic compounds. This might be attributed to the fact that heat-sensitive phenolics were degraded or bio-transformed at high temperatures. In another investigation, total phenolic content increased considerably in the leaves of oregano and peppermint when they were dried at ambient air, but no significant difference was observed for lemon balm. This investigation clearly explains that the drying process may result in high or low levels of TPC depending on the type of phenolic compounds present in the plant material and their location in the cell [44]

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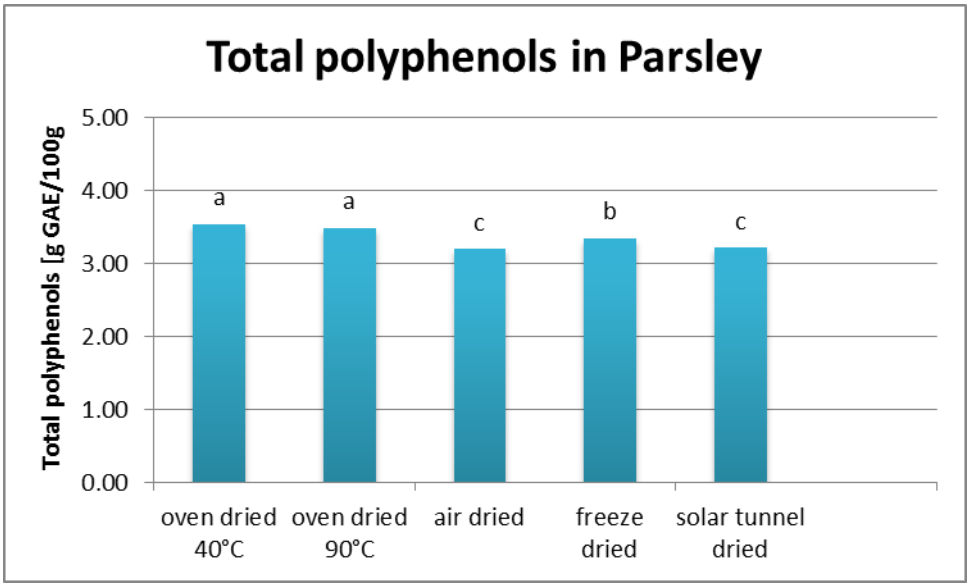

Fig 3: Effect of the drying methods on polyphenol contents of parsley

Effect of the drying methods on glucotropaeolin contents of Nasturtium:

Comparing the contents of glucotropaeolin with the original amount (determined by freeze-drying), clear differences were recorded. Freeze-dried nasturtium contained the highest levels of glucosinolates (Fig. 4). Although, freeze-drying for large amounts of plant materials is much too costly, it is the most appropriate method for drying nasturtium because only with rapid freezing of the material, losses can be avoided entirely but for all other drying variants losses of glucosinolates are unavoidable.

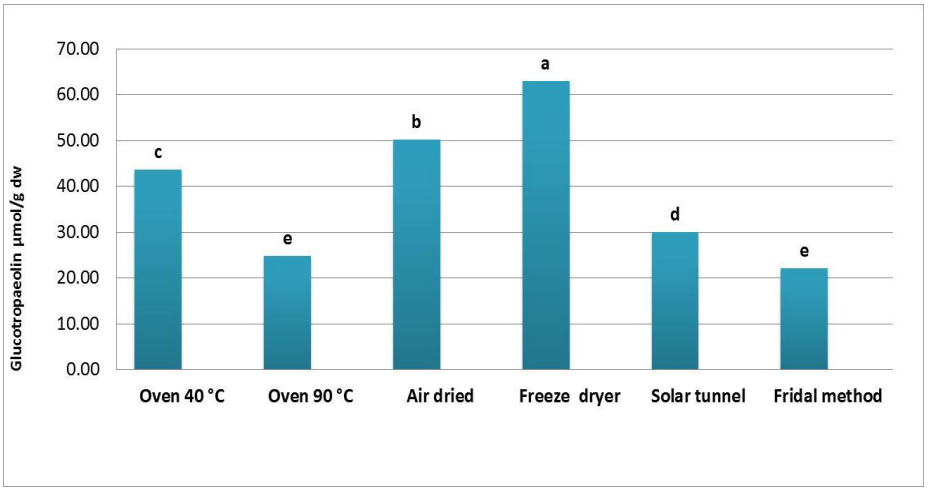

Fig 4.: Effect of the drying methods on glucotropaeolin contents of nasturtium

It was assumed that shock-freezing of the samples followed by freeze-drying would deliver the highest glucotropaeolin content because myrosinase is instantly deactivated by this treatment since the glucosinolate glucotropaeolin in nasturtium is very susceptible to hydrolysis and compartmentalization certainly leads to cleavage and mustard oils are released It must be ensured that the plant material after freezing nasturtium will not thaw to minimize degradation and this include harvesting into liquid nitrogen, and freeze drying [44].

Air drying and oven drying (40 ° C) led to good glucosinolates, slightly losses below those of the freeze-drying have been recorded. The glucotropaeolin concentrations decline to about 80% and 70% of the original amount. More than half of the Glucotropaeolins has been cleaved in the samples that dried in the solar tunnel dryer while oven drying (90 ° C) and fridal method resulted in substantial losses of glucosinolates.

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The high losses (60.3 and 66.7 %, respectively) are due to high temperatures: owing to the high thermal stress that might compartmentalize the cells of the plant material to a large extent before the water concentration reaches a low level. These results are in agreement with the result of [45] who reported that in the stem material shock-freezing yielded on average 4.8 and 7.3 µmol g−1 GTL (d.w.) higher values than drying the samples at 40 ◦C and 60◦C, respectively.

Effect of the drying methods on terpene contents of sage and parsley

Surprisingly, the concentration of terpenes presented very different results in the drying of parsley and sage. However, the drying in the solar tunnel dryer yielded the highest terpenes content, oven drying (40 ° C) and air drying gave convergent results on the concentration of terpenes in parsley. Because of the high vacuum, freeze drying resulted in a noticeable loss of terpenes. Oven dried (90 °C), and Fridal samples contained very low concentrations (Figure 5).

The sage samples gained by air drying revealed the highest terpene contents whereas, Freeze dried samples in contrast to parsley, and oven dried samples (40 °C) contained considerably massive amount of terpenes. The remaining drying variants resulted in low terpene contents.

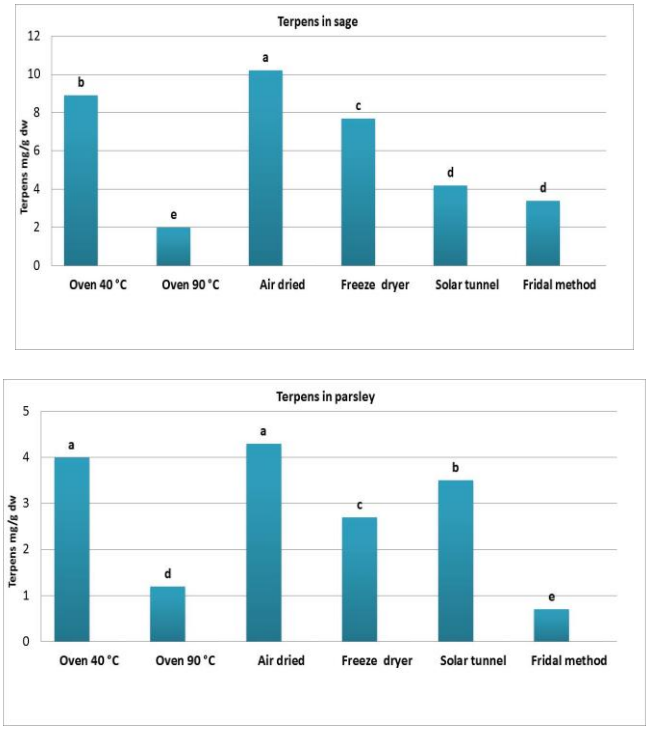

Fig 5: Effect of the drying methods on terpene contents of sage and parsley

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